

WHAT IS CLAIMED IS

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1. A method of fabricating a semiconductor device having a ferroelectric capacitor, comprising the steps of:

forming an active device element on a
10 substrate;

forming an insulation film over said substrate to cover said active device element;

forming a lower electrode layer of said ferroelectric capacitor over said insulation film;

15 forming a ferroelectric film on said lower electrode layer as a capacitor insulation film of said ferroelectric capacitor;

crystallizing said ferroelectric film by applying a thermal annealing process in an atmosphere containing a non-oxidizing gas and an oxidizing gas;
20 and

forming an upper electrode layer on said ferroelectric film.

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2. A method as claimed in claim 1, wherein said step of forming said lower electrode layer
30 includes a step of depositing a Ti layer and a Pt layer consecutively.

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3. A method as claimed in claim 1, wherein said step of crystallizing said ferroelectric film is

conducted by setting the composition of said atmosphere such ~~that~~ said atmosphere contains said oxidizing gas with a fraction of 1 - 50% in volume.

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4. A method as claimed in claim 1, wherein said non-oxidizing gas is selected from a group
10 consisting of Ar, He, Ne, Xe and N₂.

5. A method as claimed in claim 1, wherein said oxidizing gas is selected from a group consisting of O₂, N₂O, NO and NO₂.

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6. A method as claimed in claim 1, wherein said step of crystallizing said ferroelectric film is conducted by a rapid thermal annealing process.

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7. A method as claimed in claim 1, wherein
30 said step of forming said step of forming said ferroelectric film comprises the step of forming said ferroelectric film by a sputtering process.

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8. A method as claimed in claim 7, wherein

said ferroelectric film has a perovskite structure.

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9. A method as claimed in claim 8, wherein said ferroelectric film is a film of zirconate titanate of Pb.

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10. A method as claimed in claim 1, further comprising the step, after said step of crystallizing said ferroelectric film, of oxidizing said ferroelectric film in an oxidizing atmosphere.

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11. A method as claimed in claim 1, wherein said step of crystallizing said ferroelectric film is conducted under a reduced total pressure.

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12. A method of fabricating a semiconductor device having a ferroelectric capacitor, comprising the steps of:

30 forming an active device element on a substrate;

forming an insulation film over said substrate to cover said active device element;

35 forming a lower electrode layer of said ferroelectric capacitor over said insulation film;

forming a ferroelectric film on said lower

electrode layer as a capacitor insulation film of said ferroelectric capacitor;

crystallizing said ferroelectric film by applying a thermal annealing process in an atmosphere of an oxidizing gas under a reduced total pressure smaller than an atmospheric pressure; and

forming an upper electrode layer on said ferroelectric film.

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13. A method as claimed in claim 1 wherein said oxidizing gas is O_2 and wherein said total pressure is set in the range between 1 Torr and 40 Torr.

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14. A method of fabricating a semiconductor device having a ferroelectric capacitor, comprising the steps of:

forming an active device element on a substrate;

forming an insulation film over said substrate to cover said active device element;

forming a lower electrode layer of said ferroelectric capacitor over said insulation film, said lower electrode layer including a layer part containing Ti atoms;

forming a ferroelectric film on said lower electrode layer as a capacitor insulation film of said ferroelectric capacitor;

crystallizing said ferroelectric film by applying a thermal annealing process in an atmosphere of an oxidizing gas; and

forming an upper electrode layer on said ferroelectric film,

wherein said step of crystallizing said ferroelectric film is conducted by supplying O₂
5 controlled to cause an oxidation in said Ti atoms reached a surface of said lower electrode from said layer part containing Ti atoms.

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15. A semiconductor device, comprising:
a substrate;

an active device element formed on said
15 substrate;

an insulation film provided over said substrate to cover said active device element;

a lower electrode provided over said insulation film;

20 a ferroelectric film provided on said lower electrode, said ferroelectric film having a columnar microstructure extending from an interface between said lower electrode and said ferroelectric film in a direction substantially perpendicular to a principal
25 surface of said lower electrode, said ferroelectric film essentially consisting of crystal grains having a generally uniform grain diameter of less than about 200 nm; and

an upper electrode provided on said
30 ferroelectric film.

35 16. A semiconductor device as claimed in claim 15, wherein said crystal grains constituting said ferroelectric film have an average diameter of

about 150 nm.

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17. A semiconductor device as claimed in claim 15, wherein said lower electrode comprises a Ti layer and a conductor layer provided further on said Ti layer.

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18. A semiconductor device as claimed in claim 17, wherein said conductor layer is formed of Pt.

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19. A semiconductor device as claimed in claim 17, wherein said ferroelectric film has a perovskite structure.

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20. A semiconductor device as claimed in claim 19, wherein said ferroelectric film comprises a zirconate titanate of Pb.

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